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The National Ignition Facility: Status and Performance of the World's Largest Laser System for the High Energy Density and Inertial Confinement Fusion

C. A. Haynam, P. J. Wegner, G. M. Heestand, E. Moses, R. A. Sacks, M. W. Bowers, S. N. Dixit, G. V. Erbert, M. A. Henesian, M. R. Hermann, K. S. Jancaitis, K. Knittel, T. Kohut, K. R. Manes, C. D. Marshall, N. C. Mehta, J. Menapace, J. R. Murray, M. C. Nostrand, C. D. Orth, R. Patterson, R. Saunders, M. J. Shaw, M. Spaeth, S. B. Sutton, W. H. Williams, C. C. Widmayer, R. K. White, S. T. Yang, B. M. Van Wonterghem

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C.A. Haynam*, P. J. Wegner, G. M. Heestand, E. Moses, R. A. Sacks, M. W. Bowers, S. N. Dixit, G. V. Erbert, M. A. Henesian, M. R. Hermann, K. S. Jancaitis, K. Knittel, T. Kohut, K. R. Manes, C. D. Marshall, N. C. Mehta, J. Menapace, J. R. Murray, M. C. Nostrand, C. D. Orth, R. Patterson, R. Saunders, M. J. Shaw, M. Spaeth, S. B. Sutton, W. H. Williams, C. C. Widmayer, R. K. White, S. T. Yang, and B. M. Van Wonterghem,

Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA, 94550
**Corresponding author: haynam1@llnl.gov*

Abstract: The National Ignition Facility (NIF) at Lawrence Livermore National Laboratory has been designed to support a wide variety of high energy density science (HEDS) experiments, including the demonstration of inertial fusion ignition and burn. To meet this goal, its 192-beam frequency-converted neodymium-glass laser must deliver up to 1.8-MJ total energy at 351nm, with peak power of 500 TW and precisely-controlled temporal pulse shapes spanning two orders of magnitude. Over the past two years, a series of detailed measurements have been performed on one beamline of the NIF laser at 1ω(1053nm), 2ω(526.5nm), and 3ω(351 nm). Results of these experiments lend confidence to the expectation that NIF will meet its laser performance design criteria and that it will be able to simultaneously deliver the temporal pulse shaping, focal spot conditioning, peak power, shot-to-shot reproducibility, and power balance required for indirect-drive fusion ignition campaigns. The NIF final optics system has also been demonstrated to be capable of operating at 2ω energies of up to 17.9kJ/beamline—3.4MJ for a similarly configured 192-beam NIF. We discuss the status of NIF commissioning, and the nature and results of these measurement campaigns.

The NIF laser build-out and commissioning have made substantial progress since last reported [1] and are on track to support the start of 192-beam operations in mid-2009 and to begin a full scale ignition campaign in 2010. As of November 2007, 120-beams have operated at 1ω at an average of more than 20kJ/beamline, bringing the current 1ω capability to 2.5MJ. We have propagated amplified light simultaneously through 168 beamlines at the joule level to the entrance of the switchyard, verifying proper operation of key laser systems including the entire 1ω oscillator and pre-amplifier, the integrated computer control, alignment, and diagnostic systems. Installation of the Final Optics Modules on the target chamber has begun, and 3ω operations will begin in early 2008. The current NIF laser status is shown in Fig. 1.

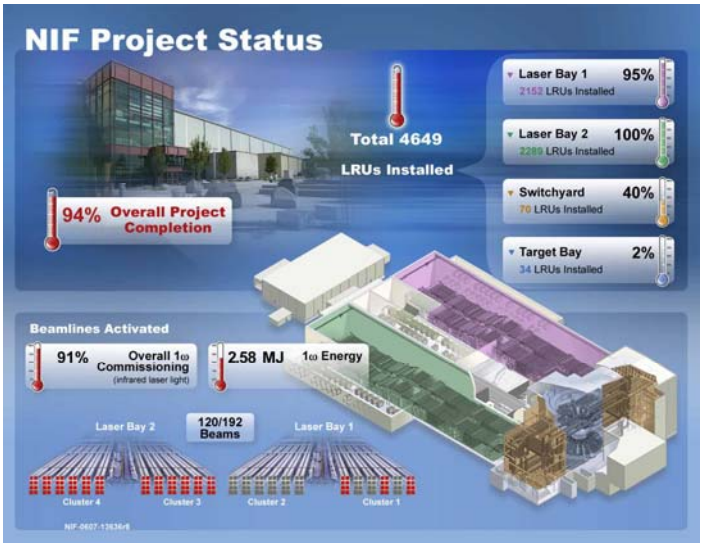

Figure 1. NIF laser commissioning status as of November 2008

We have continued to validate and refine NIF capabilities by operating a single beamline to our Precision Diagnostic Systems (PDS), where input to and output from a NIF production Final Optics System (FOS) can be analyzed in detail. As illustrated in Figure 2, we have obtained results that meet or exceed all NIF design criteria. We have also probed shot-to-

shot reproducibility and single-shot power balance by firing a series of nominally-identical shots. (Figure 3). Using an 18.2-mm-thick type I potassium dihydrogen phosphate (KDP) crystal, we operated the PDS beamline at 2ω, over a wide range of conditions at energies up to 17.9 kJ/beam (3.4 MJ for a similarly configured 192-beam NIF) (Fig.4).

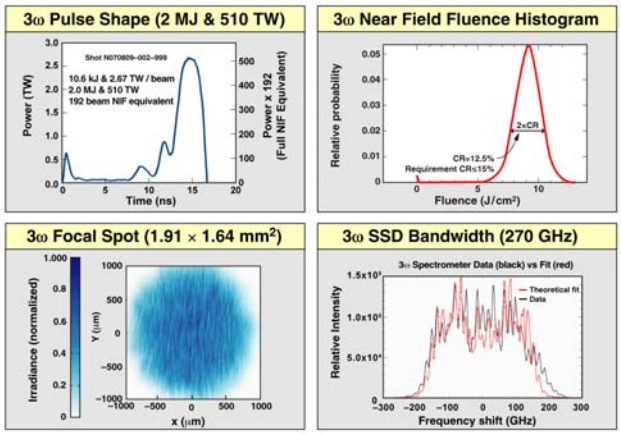

Figure 2. Conceptual 1.8 MJ NIC ignition design pulse energy, power, fluence, and focal spot conditioning were achieved simultaneously.

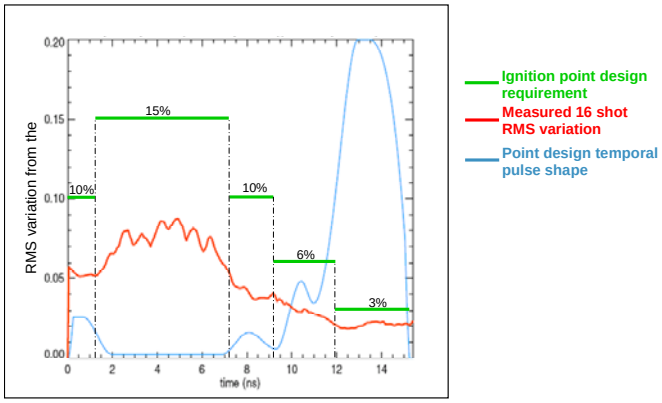

Figure 3 The time-dependent rms variation among a sets of 16 nominally-identical shots (red), compared to the NIF baseline ignition design (Rev 2) power-balance requirement (green), with the temporal pulse shape for reference (blue).

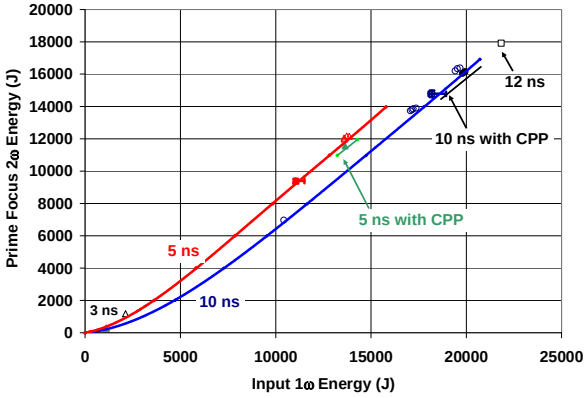

Figure 4. Measured (symbols) and modelled (solid lines) 2w output energy at the PDS equivalent target plane versus the 1w energy at the input to the final optics. System shots were taken with pulse widths from 3ns to 12ns as shown.

[1] C.A.Haynam, et.al. "The National Ignition Facility laser performance status", App Opt 46, 3276-3303 (2007)

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